# WA3-06_T4_Unregulated_StW_Lit_12_15_10.xls

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| **Date Last Modified:** | 12/15/2010 |
| **By:** | Abt Associates Inc. |
| **Data Sources:** | see "References" tab |
| **Description:** | Case studies of surface water impacts from urbanization/urban stormwater in unregulated areas |
| **Purpose:** | To compile documentation on the impact of urban stormwater in unregulated areas |

| Worksheet | Description |
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| **Unreg** | Information on published studies documenting the effect of urbanization and/or urban stormwater on surface water resources in "unregulated areas." A study was considered to be located in an unregulated area if it did not have any regulated areas upstream |
| **Unreg Refs** | Full citation for all the studies cited in "Unregulated Case Studies" |

**Abbreviations:**

IS = impervious surface
LU = land use
FC = fecal coliform
BOD = biological oxygen demand (when not specified, traditionally refers to 5-day BOD)
BOD5 = 5-day BOD
BOD20 = 20-day BOD
TSS = total suspended solids
TN = total nitrogen
DIN = dissolved inorganic nitrogen
TP = total phosphorous
ortho-P = orthophosphate
DO = dissolved oxygen
OC = organic carbon
USGS = US Geological Survey
TOC = total organic carbon
GIS = geographic information system

| Author, Year | Title | Location | Locational Data | Surface Water Name | Surface Water Type | Regulated under Phase I or Phase II (yes/no) | Source(s) of Impairment | Urban Indicators Tested | In-Stream Impairments Based on All Sites in the Study[1] |
|---|---|---|---|---|---|---|---|---|---|
| Mallin et al., 2009 | Comparative impacts of stormwater runoff on water quality of an urban, a suburban, and a rural stream | Pender and New Hanover counties, near Wilmington, NC | Map, text | Prince Georges Creek (PGC) | Coastal stream | No.<br><br>(2 Phase I streams were also part of the study but excluded from this table) | For the PGC temporal study: rainfall<br><br>For spatial comparison among three streams: LU (residential, commercial/industrial, agricultural/forestry, undeveloped) and IS | For PGC, total rainfall within 24, 48, and 72 hours before sampling regressed against in-stream variables<br><br>Among three streams, rgressed land use including residential and commercial/industrial LU and impervious cover (IS range 4.8-13.4%) against in-stream physiochemical variables | For PGC, total rainfall within 72 hours of sampling was significantly correlated with:<br>• increased FC, TSS, turbidity, ortho-P, TP, and BOD20<br>• decreased ammonium and grease/oil |
| Tang et al., 2005 | Forecasting land use change and its environmental impact at a watershed scale | Michigan | Good Map | Muskegon Lake watershed, 40 subwatersheds | Streams | No.<br><br>(1 subwatershed was Phase II and is excluded from this table) | LU: agricultural, forest, water/wetlands, and urban (commercial, industrial, high density residential, low density residential, and grass/pasture) | Urban LU (low density residential and industrial was 85% of the total urban area) | Modeling results indicate that from 1978-2040 urbanization will:<br>• for the non-sprawl scenario, slightly increase runoff volume and nutrient losses and significantly increase the lossess of oil and greas and nickel<br>• for the sprawl scenario, runoff volumes will be more pronounced, nutrient loss increases will be about the same, and heavy metals and oil and grease losses will more than double compared to the non-sprawl scenario |
| Wenger et al., 2008 | Stream fish occurrence in response to impervious cover, historic land use, and hydrogeomorphic factors | Georgia | Good Map | Etowah River basin, ~80 sample sites | Streams | No.<br><br>(~80% of sites were Phase I or II and were excluded from this table) | Exisiting LU and effective impervious area (EIA), historical LU, and historical reservoirs | EIA | The best regression model included EIA and showed:<br>• The occurrence of several species was strongly negatively related to EIA<br>• Some species become rare at 2% EIA |
| Horowitz and Stevens, 2008<br><br>Mueller and Spahr, 2006 | The effects of land use on fluvial sediment chemistry for the conterminous U.S. — Results from the first cycle of the NAWQA Program: Trace and major elements, phosphorus, carbon, and sulfur<br><br>Nutrients in Streams and Rivers Across the Nation — 1992–2001 | USA | Map | 52 study units, ~459 sites | Streams | No.<br><br>(55% of sites were within 5 miles or in a Phase I and II Area and, therefore, excluded from this table) | Land use: agricultural, urban, undeveloped (forest and rangeland), mixed | Urban LU | Increased urban LU is associated with increased concentrations of trace elements, ranging from 1.5 to nearly 5 times background concentrations<br><br>For urban sites with no known WWTPs, 21% of ammonia, 17% of orthophosphate, and 16% of total phosphorus water quality measurements were in the upper quartile (above the 75th percentile) for all sites. |
| Lussier et al., 2008 | The influence of suburban land use on habitat and biotic integrity of coastal Rhode Island streams | Narragansett Bay, RI | Map, text | Wood River and Adamsville Brook, RI | Wadeable, coastal stream reaches | No.<br><br>(6 study sites were Phase I and excluded from this table) | Suburban development with no known point sources of nitrogen | Residential land use (for Wood River and Adamsville Brook residential LU was 4 and 12%, respectively, with IS of 1 and 3%, respectively) | Increasing residential LU significantly correlated with:<br>• decrease in indicators for stream physicochemical, habitat, and instream biodiversity<br>• most responsive physicochemical variables were dissolved inorganic nitrogen (DIN), conductivity, nitrate, instream habitat<br>• shift in biotic composition of the streams from sensitive to insensitive taxa |

Studies on the Surface Water Impacts of Urbanization and Urban Stormwater from Unregulated Areas*
*A study was considered to be located in an unregulated area if it did not have any regulated areas upstream in its watershed.

| Author, Year | Title | Location | Locational Data | Surface Water Name | Surface Water Type | Regulated under Phase I or Phase II (yes/no) | Source(s) of Impairment | Urban Indicators Tested | In-Stream Impairments Based on All Sites in the Study[1] |
|---|---|---|---|---|---|---|---|---|---|
| Marchetti et al., 2006 | Effects of urbanization on California's fish diversity: Differentiation, homogenization and the influence of spatial scale | CA | Map | ~15 streams/subwatersheds in Northern and Eastern CA | Streams | No.<br><br>(~30 watersheds were Phase I and II and excluded from this table) | • Hydrologic alteration (dams, reservoir area, ditch density, and aqueduct density)<br>• LU (developed, agriculture, and high protection status)<br>• Environmental characteristics (mean elevation, mean rainfall, stream length, and watershed area) | Urban LU (commercial, industrial, urban, suburban, transportation, mines, and quarries) | Increased urban LU is highly positively correlated with:<br>• endangerment of native fish,<br>• invasion of non-native fish within watersheds, and<br>• diversification of fish populations. |
| Morse et al., 2003 | Impervious surface area as a predictor of the effects of urbanization on stream insect communities in Maine, USA | Anson/Madison and Augusta, ME | Rough map | Ansor/Madison and Augusta Rivers | Streams | No.<br><br>(Two other sites in Bangor and S.Portland are Phase II and were excluded from this table.) | Total impervious area (TIA) | TIA ranging from 1-26% | Increasing TIA was correlated to:<br>• Decrease in macroinvertebrate taxonomic richness with abrupt change above a TIA threshold of 6%<br>• Linear decrease in habitat and water quality |
| Rothenberger et al., 2009 | Long-term effects of changing land-use practices on surface water quality in a coastal river and lagoonal estuary | Neuse River, NC | Rough map | 5 streams within the Neuse River watershed | Streams | No.<br><br>(~80% of the 26 study sites were Phase I or II and were excluded from this table) | LU (urban, agriculture, forested, wetland), number of WWTPs, package plants, CAFOs, and swine operations, and precipitation | Urban LU | Increased urban LU significantly increased:<br>• soluble reactive phosphorus (SRP), TN, nitrate, and total Kjeldal nitrogen (TKN) |
| Schoonover et al., 2006 | Impacts of land cover on stream hydrology in west Georgia Piedmont | Between Columbus and LaGrange, GA | Map, coordinates | 14 streams/ subwatershed outflow points in the Middle Chattahoochee Watershed | Streams | No.<br><br>(~4 outflows points were Phase II and were excluded from this table) | LU (urban, developing, pasture, managed, unmanaged) | Urban LU | Increased IS:<br>• increased flashiness, more frequent high flow pulses, and elevated peak discharges |
| Sprague et al., 2007 | Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States | Portland, OR | Map | 11 streams/sub-watersheds | Stream baseflow | No.<br><br>(~60% subwatersheds were Phase I and II and excluded from this table) | 11 urban variables including urban LU, population density, and road density | Urban LU | Increased urbanization was correlated to:<br>• increased concentrations of nitrogen, total herbicides and total insecticides in streams. |
| Sprague et al., 2007 | Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States | Atlanta, GA | Map | 9 streams/sub-watersheds | Stream baseflow | No.<br><br>(~70% of subwatersheds were Phase I and II and excluded from this table) | 11 urban variables including urban LU, population density, and road density | Urban LU | Increased urbanization was correlated to:<br>• increased concentrations of nitrogen, total herbicides and total insecticides in streams. |

| Author, Year | Title | Location | Locational Data | Surface Water Name | Surface Water Type | Regulated under Phase I or Phase II (yes/no) | Source(s) of Impairment | Urban Indicators Tested | In-Stream Impairments Based on All Sites in the Study[1] |
|---|---|---|---|---|---|---|---|---|---|
| Sprague et al., 2007 | Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States | Green Bay-Milwaukee, WI | Map | 8 sub-watersheds | Stream baseflow | No.<br><br>(~70% of subwatersheds were Phase I and II and excluded from this table) | 11 urban variables including urban LU, population density, and road density | Urban LU | Increased urbanization was correlated to:<br>• no change or decreased concentrations of nitrogen, total herbicides<br>• increased total insecticides in streams. |
| Sprague et al., 2007 | Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States | Denver, CO | Map | 1 sub-watershed near Cheyenne | Stream baseflow | No.<br><br>(~95% of subwatersheds were Phase I and II and excluded from this table) | 11 urban variables including urban LU, population density, and road density | Urban LU | Increased urbanization was:<br>• weakly correlated to increased total nitrogen concentrations<br>• correlated increased total insecticides in streams. |
| Sprague et al., 2007 | Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States | Raleigh-Durham, NC | Map | 5 sub-watersheds | Stream baseflow | No.<br><br>(~80% of subwatersheds were Phase I and II and excluded from this table) | 11 urban variables including urban LU, population density, and road density | Urban LU | Increased urbanization was correlated to:<br>• increased concentrations of nitrogen, total herbicides and total insecticides in streams. |
| Sprague et al., 2007 | Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States | Dallas-Fort Worth, TX | Map | 13 sub-watersheds | Stream baseflow | No.<br><br>(~55% of subwatersheds were Phase I and II and excluded from this table) | 11 urban variables including urban LU, population density, and road density | Urban LU | Increased urbanization was correlated to:<br>• no change or decreased concentrations of nitrogen, total herbicides<br>• increased total insecticides in streams. |
| Horwitz et al., 2008 | Effects of riparian vegetation and watershed urbanization on fishes in streams of the mid-Atlantic Piedmont (USA) | PA, MD, NJ, DE | Map, coordinates | 11 study sites | Watersheds | No.<br><br>(~70% of subwatersheds were Phase I and II and excluded from this table) | Land use including urban (parking lots, roads, residential, residential, commerical, industrial), forested, agriculture | Urban LU (parking lots, roads, residential, residential, commerical, industrial) | Increased urbanization was correlated to:<br>• decreased populations of intolerant species<br>• increased populations of tolerant species and omnivores |
| Paul et al., 2009<br><br>Purcell et al., 2009 | Assessment tools for urban catchments: defining observable biological potential<br><br>Assessment tools for urban catchments: developing biological indicators based on benthic macroinvertebrates | Cleveland, OH | Map, text | ~60 sampling sites | Streams | No.<br><br>(~50% of sampling sites were Phase I or II and are excluded from this table) | Primary urban gradient index (including population density, road density, and urban LU/LC) | Urban gradient | Increased urbanization limits the upper boundary of the final biological index. |
| Randhir and Ekness, 2009 | Urbanization effects on watershed habitat potential: a multivariate assessment of thresholds and interactions | Westfield River, MA | Rough map | Westfield River and its tributaries<br><br>(~110 subbasins) | Streams | No.<br><br>(~25% of the subbasins are regulated and were excluded from this table) | IS (~0-25%), LU disturbance, habitat fragmentation, population density, and open space | IS, population density, average size of forest patch, number of forest patches, open space, and land use disturbance | Non-linear relationship between habitat potential/occurrence of vertebrates and IS. Habitat potential increases and then declines above the following thresholds:<br>•amphibians- 13% IS<br>•reptiles- 12% IS<br>•birds- 11% IS<br>•mammals- 10% IS |
| Weston et al., 2009 | Population growth away from the coastal zone: Thirty years of land use change and nutrient export in the Altamaha River, GA | Central GA | Map | Ohoopee River | Coastal stream | No.<br><br>(Six other USGS station data were excluded as they were downstream of regulated areas) | Population density and LU change | Increased population (decreased agricultural land) | Increased population density and decreased agricultural land use:<br>• Increased concentrations of nirate+nitrite<br>• Decreased concentrations of ammonium and total phosphorous |

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|---|---|---|---|---|---|---|---|---|---|
| Cianfrani et al., 2006 | Watershed imperviousness impacts on stream channel condition in Southeastern Pennsylvania | Piedmont Uplands Physiographic Province, Pennsylvania | Good Map | 13 stream reaches | Stream | No.<br><br>(~70% of sampling sites were Phase I or II and are excluded from this table) | TIA | TIA | For all streams (TIA ranged 0-75%), TIA was:<br>• Positively correlated to the number of large woody debris (LWD) pieces per channel width of stream<br>• Weakly negatively correlated to sinuosity<br><br>For streams >24% TIA, TIA was:<br>• Negatively correlated to depth diversity and the standard deviation of the maximum pool depths for each stream reach |
| Slawski et al., 2008 | Effects of tributary spatial position, urbanization, and multiple low-head dams on watermwater fish community structure in a Midwestern Stream | Illinois and Wisconsin | Good Map | 14 sampling sites in the Des Plaines River watershed | Streams | No.<br><br>(~65% of sampling sites were Phase II and are excluded from this table) | LU: urban, agriculture, "natural landscape" (wetlands, woodlands, other open lands); spatial position of tributaries within watershed, and presence of low-head dams | Urban LU | • Urbanization in undammed tributaries led to shift from coolwater-riverine specialist to warmwater riverine generalist assemblages<br>• Land use change from agriculture to urban was negatively correlated to fish diversity |
| Tong and Chen, 2002 | Modeling the relationship between land use and surface water quality | Ohio | Good map | East Fork Little Miami River Basin, 8 subwatersheds | Subwatershed | No.<br><br>(~30% of subwatersheds were Phase I or II and were excluded from this table) | LU: urban (residential, commercial), forest, agricultural, barren land, water | Urban LU (residential, commercial) | Urban LU was:<br>• strongly positively correlated to TN, TP, and FC<br>• related to sodium, cadmium, lead, conductivity, BOD, and zinc |

Notes:

IS = impervious surface, LU = land use, FC = fecal coliform; ortho-P = orthophosphate, BOD = biological oxygen demand, TSS = total suspended solids; TN = total nitrogen, TP = total phosphorous, DO = dissolved oxygen, OC = organic carbon
[1] In-stream impairments are cited from the study and, unless otherwise noted, the results are from the analysis of all sites (e.g., regulated and unregulated). To determine whether these trends are present in only the unregulated sites, the data needs to be re-analyzed with only the unregulated sites.

| Author, Year | Data/Documented Correlation for Unregulated Areas | All Environmental Response Variables Tested | Additional Data/Notes |
|---|---|---|---|
| Mallin et al., 2009 | Yes- sufficient data available in study to examine temporal trends within unregulated area (PGC) and authors stated conclusions for individual streams for rainfall correlation. | Water quality: temperature, conductivity, salinity, DO, turbidity, TSS, ammonium, nitrate, TN, ortho-P, TP, total organic carbon, chlorophyll a, BOD5, BOD20, FC, surfactants, grease/oil | Regression across all three streams showed that increased development and IS percent were strongly correlated with:<br>• increased BOD, ortho-P, and surfactant concentrations<br>• decreased TOC<br><br>Turbidity and TSS were positively correlated with phosphorous, FC, BOD, and chlorophyll a.<br><br>Additional data:<br>• daily rainfall<br>• GIS data including position of samples, land use, IS |
| Tang et al., 2005 | Yes, time-series data for unregulated areas can be estimated from graph. | Water quality: nutrients (nitrogen, phosphorus); heavy metals; oil and grease | Forecasted changes in land use based on 1978 LU data for 2 scenarios: non-sprawl growth (based on the lowest expansion index found in MI); sprawl-growth (high expansion index based on 17 counties for a 17-year period) |
| Wenger et al., 2008 | Need to contact author to get data and determine what EIA threshold corresponded to unregulated site. | Biotic: fish distribution, occurrence | When existing and historic LU were regressed separately, current land use was a slightly more accurate predictor of fish occurrence than historic LU. |
| Horowitz and Stevens, 2008<br><br>Mueller and Spahr, 2006 | Need to contact author to determine which data in the study are located in unregulated areas. | Water quality: trace element and nutrient concentrations | |
| Lussier et al., 2008 | Need to contact author for data and determine whether trends also exist in the two unregulated areas. | • Physicochemical variables: temperature, dissolved oxygen (DO), pH, conductivity, stream flow, nutrients (ammonia, nitrate, nitrite, phosphorous)<br>• Habitat: substrate, channel morphology (channel width and depth), bank structure, riparian vegetation, habitat assessment score (based on EPA Rapid Bioassessment Protocols), benthic macroinvertabrates | • Rhode Island Geographic Information System<br>• 3 annual samples for all environmental response variables<br>• Percent impervious surface (1-47%) |

| Author, Year | Data/Documented Correlation for Unregulated Areas | All Environmental Response Variables Tested | Additional Data/Notes |
|---|---|---|---|
| Marchetti et al., 2006 | Need to contact author for data and determine whether trends also exist in unregulated areas. | Biotic: presence/absence of native/non-native fish, changes in fish diversity | |
| Morse et al., 2003 | Need to contact author for data and determine whether trends also exist in unregulated areas. | Biotic: changes in taxonomic richness in insect species<br><br>Hydrogeomorphology: habitat quality (bankfull width and depth, wetted width and depth, bank erosion and angle, percent substrate, and riparian width and forest-type); physical stream condition (Qualitative Habitat Index, Stream Reach Inventory and Channel Stability Index),<br><br>Water quality: temperature, pH, DO, specific conductance, nutrients (nitrogen and phosphorus), and TSS) | • TIA for all sites ranged from 1-31% |
| Rothenberger et al., 2009 | Need to contact author for data and determine whether trends also exist in unregulated areas. | Water Quality: TP, SRP, nitrate, ammonium, TKN | |
| Schoonover et al., 2006 | Need to contact author for data and determine whether trends also exist in unregulated areas. | Hydrology: stage, discharge, flow (frequency, magnitude, duration, predictability, flashiness), precipitation data (from which, calculated Runoff Coefficients) | |
| Sprague et al., 2007 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: nutrients pesticides, pH, sulfate and chloride | Samples taken twice a year for 2 years under base flow conditions<br><br>Extensive GIS data is available, including 300 urban and environmental variables (e.g., population, housing, climate, land cover, infrastructure, and ecoregions) |
| Sprague et al., 2007 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: nutrients pesticides, pH, sulfate and chloride | Extensive GIS data is available, including 300 urban and environmental variables (e.g., population, housing, climate, land cover, infrastructure, and ecoregions) |

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|---|---|---|---|
| Sprague et al., 2007 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: nutrients pesticides, pH, sulfate and chloride | Extensive GIS data is available, including 300 urban and environmental variables (e.g., population, housing, climate, land cover, infrastructure, and ecoregions) |
| Sprague et al., 2007 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: nutrients pesticides, pH, sulfate and chloride | Extensive GIS data is available, including 300 urban and environmental variables (e.g., population, housing, climate, land cover, infrastructure, and ecoregions) |
| Sprague et al., 2007 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: nutrients pesticides, pH, sulfate and chloride | Extensive GIS data is available, including 300 urban and environmental variables (e.g., population, housing, climate, land cover, infrastructure, and ecoregions) |
| Sprague et al., 2007 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: nutrients pesticides, pH, sulfate and chloride | Extensive GIS data is available, including 300 urban and environmental variables (e.g., population, housing, climate, land cover, infrastructure, and ecoregions) |
| Horwitz et al., 2008 | Need to contact author for data and determine whether trends exist in unregulated areas. | Biotic: fish assemblage structure (abundance, diversity, richness, biomass)<br><br>Geomorphic: wetted channel width, depth, slope, %pool, %riffle, median grain size | Unregulated sites include only forested (vs. nonforested) sites. |
| Paul et al., 2009<br><br>Purcell et al., 2009 | Need to contact author for data and determine whether trends exist in unregulated areas. | The final biological index was composed of the metrics EPT richness, filterer richness, and percent clingers. | Primary urban gradient index was developed in Bressler et al. 2009 |
| Randhir and Ekness, 2009 | Need to contact author for data and determine whether trends exist in unregulated areas. | Biotic: distribution of vertebrate species | All data was compiled in GIS |
| Weston et al., 2009 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: TN, TP, Nitrate+nitrite, ammonium, organic carbon, discharge, temperature (30 years of data from USGS station) | GIS data on at least location of gages, population and agricultural LU |

| Author, Year | Data/Documented Correlation for Unregulated Areas | All Environmental Response Variables Tested | Additional Data/Notes |
|---|---|---|---|
| Cianfrani et al., 2006 | Need to contact author to determine which data in the study are located in unregulated areas. | Geomorphic and habitat variables: bankfull width, bankfull depth, pools per channel width, thalweg depth : pool depth, bed sediment diameter, category of large woody debris (LWD), number of LWD pieces per channel widths of stream, embeddedness, sinuosity | |
| Slawski et al., 2008 | Need to contact author to determine which data in the study are located in unregulated areas. | Biotic: fish community diversity and composition | |
| Tong and Chen, 2002 | Need to contact author for data and determine whether trends exist in unregulated areas. | Water quality: conductivity, BOD, pH, total nitrogen, total phosphorus, sodium, cadmium, lead, manganese, zinc, fecal coliform | Agricultural LU was also strongly positively correlated to TN, TP, and FC.<br><br>Modeling results for one site which was located within a Phase II regulated area showed:<br>• Impervious lands produced >55 times as much runoff as pervious lands (surface flow from the impervious urban lands was 26.59 cm/day and from agricultural lands was 0.46 cm/day)<br>• Surface flow and pollutant graphs for the impervious lands for all subwatersheds approximated that of the precipitation curves. Stream flow and, to a certain extent, water quality is therefore primarily determined by rainfall. |

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| Cianfrani, CM, et al. (2006). Watershed imperviousness impacts on stream channel condition in southeastern Pennsylvania. Journal of the American Water Resources Association **42**: 941-956. |
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| Slawski, TM, et al. (2008). Effects of tributary spatial position, urbanization, and multiple low-head dams on warmwater fish community structure in a Midwestern stream. North American Journal of Fisheries Management **28**: 1020-1035. |
| Sprague, LA, et al. (2007). Response of Stream Chemistry During Base Flow to Gradients of Urbanization in Selected Locations Across the Conterminous United States, 2002–04. U.S. Department of the Interior, U.S. Geological Survey. |
| Tang, Z, et al. (2005). Forecasting land use change and its environmental impact at a watershed scale. Journal of Environmental Management **76**: 35-45. |
| Tong, S and Chen, W. (2002). Modeling the relationship between land use and surface water quality. Journal of Environmental Management **66**: 377-393. |
| Wenger, SJ, et al. (2008). Stream fish occurrence in response to impervious cover, historic land use, and hydrogeomorphic factors. Canadian Journal of Fisheries and Aquatic Sciences **65**: 1250-1264. |
| Weston, NB, et al. (2009). Population growth away from the coastal zone: Thirty years of land use change and nutrient export in the Altamaha River, GA. Science of the Total Environment **407**: 3347-3356. |